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THE BORDER-LINE BETWEEN PALEOZOIC AND MESOZOIC IN WESTERN AMERICA

THERE have been in recent years in America many controversies as to the Silurian-Devonian and the Devonian-Carboniferous boundaries; but American geologists have always felt secure as to the line of demarcation between the Paleozoic and the Mesozoic. This has always been thought to be marked by a grand chasm, a hiatus in stratigraphy and a break in life, accompanying a great change in physical geography, all of which is true of the region east of the Rocky Mountains.

But later discoveries in the Great Basin region have shown that the gap is at least partly filled out by marine sediments, and that the hiatus is not universal in America. The most important of these discoveries was the finding of marine Permian in northern Texas, with forms suggestive of the Mesozoic types of life, and the finding in southeastern Idaho of marine Lower Trias, with a fauna reminiscent of the Paleozoic.

Recently there has been evident among geologists a tendency to revert to first conditions in determining the boundaries of geologic systems. They have been inclined to use unconformities as the dividing lines between geologic groups, and to look upon geologic systems as realities, and not mere names for the convenience of stratigraphers. This must mean that they regard the geologic events that delimited the systems as of world-wide effectiveness, or even of cosmic origin. But almost every trangression of the sea has been found to be balanced by a retreat elsewhere, every uplift to have its correlative subsidence. And in still other parts of the earth there may have been neither uplift nor subsidence. Even the Appalachian revolution did not effect the western Carboniferous Sea, and this is generally admitted to have been one of the greatest events in the dynamic history of North America.

In defining the upper Paleozoic and the lower Mesozoic no account was taken of conditions of formation, and this has led to endless difficulties in correlation. The Upper Carboniferous was based entirely on lacustrine deposits, and the identification of its marine equivalent is still making trouble for geologists. The Permian was based on a basin deposit, partly lacustrine and partly of brackish water origin, and the recognition of its purely marine types has caused much controversy in Europe and America. The Trias was based at first entirely on the deposits of the Germanic inland sea, and only recently has any uniformity been attained in its correlation and nomenclature.

The greater divisions are now all named, and there is no room for new systems, all geologic time, and possibly something over, being taken up by those already defined. But because the first naming of geologic divisions was based on unconformities, which represented erosion intervals and consequent gaps in the record, further exploration must necessarily bring to light somewhere in the world passage beds between the artificial systems. What rules then shall be followed in the correlation of these passage-beds, or new formations? If the new formations are shown to be the homotaxial equivalents of parts of systems already defined, there can be no question, for faunal or lithologic differences cannot be taken in account in different provinces or regions.

If the new formation, however, lies between two systems, one of which is sharply defined and the other described only vaguely, as including the beds below or above the one with definite boundaries, then the passage-beds must naturally be assigned to the system with a flexible margin.

If both the bordering systems should be definitely bounded, or if neither should be, then one or the other must be stretched to take in the passage-beds, and the assignment will be based on paleontologic relationship to one or the other. But if this relationship should be no closer to one than the other, then priority of assignment would have to decide on the nomenclature of the doubtful beds.

The geologists of India have for many years recognized that in the Himalayas and the Salt Range there was a continuity of life and sedimentation from the Paleozoic into the Mesozoic, and there the line of demarcation has been arbitrary. The stages or zones used in drawing this paleontologic line in India have become types, and are used in interregional correlation wherever similar beds are known. A section is given below of the uppermost Permian and the Lower Trias of India, for convenience of comparison with the American section.

SECTION OF THE PERMIAN AND LOWER TRIAS OF INDIA AFTER WAAGEN, DIENER, AND NOETLING

Trias	Middle	Upper Ceratite limestone.	
	Lower	Ceratite sandstone	Flemingites beds.
			Stachella beds.
		Otoceras beds	Ceratite marls.
			Lower Ceratite limestone.
Permian	Upper	Upper Productus limestone, with *Cyclolobus oldhami*, and *Xenaspis carbonaria*.	
		Middle Productus limestone, with *Xenaspis carbonaria*.	
	Lower	Lower Productus limestone, with *Fusulina kattaensis*.	
		Glacial beds.	

Waagen drew the line between Paleozoic and Mesozoic at the base of the Ceratite formation because of a supposed unconformity, and because the Permian types of brachiopods such as *Productus*, *Chonetes*, and the Orthidae have not been found above this line. But the unconformity has since been shown not to exist, and several of the Permian ammonite genera range up into the Ceratite formation, such as *Otoceras*, *Medlicottia* and *Xenaspis*.

The upper Productus limestone is acknowledged to be younger than any known European marine Permian, and the *Otoceras* beds are universally considered to be older than any Trias yet known from Europe; therefore the continuity of sedimentation and life makes it exceedingly difficult to draw a line that will satisfy everybody. And, indeed, if either the Trias or the Permian had been named first in India, there would have been no division of this series.

The Wichita Permian of Texas, while carrying forms such as *Medlicottia*, *Waagenoceras*, and *Popanoceras*, harbingers of the varied Triassic ammonites of later times, contains in its other members so many Paleozoic types that no one would think of classing it in the Mesozoic. There can be no controversy as to its age, which is approximately equivalent to that of the lower Productus limestone of India. It lies conformably on the Coal-measures, and contains many species that have ranged up from the latter.

But above the Wichita Permian lies the great series of the Red Beds. These have been assigned sometimes to the Permian and sometimes to the Trias, and they, doubtless, belong to both. Marine fossils have been found in these Red Beds only in three places. The Geological Survey of Texas[1] found in the Double Mountain formation at the falls of Salt Croton Creek, Kent county, Texas, *Medlicottia*, *Waagenoceras*, and *Pleurophorus*, all akin to forms from the Wichita beds. The writer has examined these forms and recognizes them to be still typically Permian in character, although they are very near the top of the formation. Above these beds lies the fresh water "Dockum" series referred by Cope to the Trias.

C. N. Gould[2] has recently found marine and brackish-water Permian fossils in the Red Beds of Oklahoma, in the Cimmaron series; the forms still being of Paleozoic type, such as *Conocardium*, *Aviculopecten*, *Schizodus*, *Pleurophorus*, and *Bakevellia*. The stratigraphic position of these is equivalent to the Double Mountain beds of Texas, and they belong unequivocally to the Paleozoic.

In the Red Beds of Utah, at Ft. Douglas near Salt Lake City, F. Frech[3] has found *Pleurophorus imbricatus* Waagen, *Allorisma* conf. *elegans* King, *Emondia aspinwallensis* Meek, *Schizodus schlotheimi* King, and *Dalmanella* sp. indet., a fauna that would pass for Paleozoic anywhere, and belongs in the same horizon as the Double Mountain beds of Texas and the Cimmaron series of Oklahoma and Kansas. They are the homotaxial equivalents of the Upper Permian.

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[1] Geological Survey of Texas, Second Annual Report, 1890. Report on the Geology of Northwestern Texas, by W. F. CUMMINS, p. 408.

[2] JOUR. GEOL., Vol. IX, 1901. No. 4, p. 337.

[3] Lethaea Geognostica, Vol. II, Lieferung 3. 1900, p. 515.

From the close of the Coal-measures the land encroached on the basin-sea by a progressive westward uplift, and the brackish water and basin deposits take a successively higher place in the geologic column towards the west. Thus somewhere in the eastern part of the Great Basin region marine intercalations of Lower Trias may be expected to be found in the Red Beds. Indeed, this formation in southeastern Idaho lies above and conformably upon the marine limestones with a Lower Triassic fauna. It is, then, in the upper part of this Red Beds formation, in the fresh and brackish-water deposits and its rare marine facies, that we are to seek for the transition from Paleozoic to Mesozoic.

C. A. White[1] has described from the Aspen Mountains of Idaho a marine fauna older than any Trias known up to that time in America, and younger than any known Permian. The Meekoceras beds in which this fauna was found he assigned to the Lower Trias. According to A. C. Peale[2] this formation lies conformably upon the Carboniferous, and below the Red Beds. The *Meekoceras* fauna was found near the base of the series, which here has a thickness approximating three thousand feet. The Carboniferous limestone below contained *Productus multistriatus* Meek, which has been found by the writer in the uppermost Paleozoic beds of California, and has been cited as a characteristic fossil of the Permian of northern Europe.

Since that time Professor Alpheus Hyatt and the writer have visited the Meekoceras beds, and their joint collections yielded; *Meekoceras gracilitatis* White, *M.* (*Gyronites*) *aplanatum* White, *M.* (*Koninckites*) *mushbachanum* White, *Aspidites*, *Flemingites*, *Pseudosageceras*, *Ussuria*, *Ophiceras*, *Clypites*, *Danubites*, *Nannites*, and a number of new genera.

The writer[3] has previously described the Ceratite limestone of the Lower Trias of Inyo county, California. During the past winter he has visited this locality and added a great many species and genera to the collection from that formation. Those now known from there are: *Meekoceras gracilitatis* White, *M.* (*Gyronites*) *aplanatum* White, *M.* (*Koninckites*) *mushbachanum* White, *M.* conf. *radiosum* Waagen, *M.* conf. *falcatum* Waagen, *M.* aff. *boreale* Diener, *Aspidites*, *Prionolobus*, *Danubites*, *Proptychites*, *Xenaspis*, *Lecanites*, *Nannites*, *Ussuria*, *Pseudosageceras*, and *Clypites*, besides a number of new genera. Several of the species, both new and described, are identical with forms from the *Meekoceras* beds of southeastern Idaho, with no greater difference in the fauna than might be expected in localities separated by six hundred miles.

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[1] Twelfth Ann. Rep. U. S. Geol. and Geog. Surv. Terr., Part I (1880). Triassic Fossils from Southeastern Idaho.

[2] Bull. U. S. Geol. and Geog. Surv. Terr., Vol. V., No. 1 (1879). Jura-Trias Section of Southeastern Idaho and Western Wyoming, p. 119.

[3] JOUR. GEOL., Vol. VI, No. 8, 1898. Geographic Relations of the Trias of California.

Below the *Meekoceras* beds of Inyo county lie several hundred feet of barren shales, and below these is siliceous limestone containing *Fusulina*. Above the *Meekoceras* beds are eight hundred feet of calcareous shales with impressions of ammonites, and then a few feet of black limestone with *Acrochordiceras*, *Hungarites*, *Tirolites*, *Ceratites*, and *Xenodiscus*, and *Parapopanoceras*, probably belonging to the base of the Middle Trias. The entire series appears to be conformable, from the Upper Carboniferous to the Middle Trias.

The fauna of the *Meekoceras* beds of Idaho and California is most intimately related to that of the Ceratite formation of India, and of the homotaxial *Proptychites* beds of Ussuri in eastern Siberia. *Meekoceras*, *Gyronites*, *Koninckites*, *Danubites*, *Proptychites*, and *Ophiceras* are known both in the Ceratite formation of India, and in the Ussuri beds of Siberia; *Pseudosageceras* and *Ussuria* are known elsewhere only in the Ussuri formation; and the species of all these regions are nearly related, in part apparently identical.

It is, therefore, plain that the correlation of the Ceratite formation of India has a direct bearing on the determination of the age of the Meekoceras beds of America. Albert Oppel, who in 1865 described fossils from the Ceratite formation of India, referred them at first to the Jura, and then afterwards to the Trias, as typical Jurassic beds were found considerably above them. But before this, in 1863, de Koninck, who also described a number of ammonites from the Ceratite formation, referred them very doubtfully to the Paleozoic, because they were supposed to have come from the Productus limestone. C. L. Griesbach[1] who first described the fauna of the *Otoceras* beds of India, referred them to the Lower Trias, in which he has been followed by Wilhelm Waagen[2] and Carl Diener.[3] These writers consider the lower part of the Ceratite formation to be younger than any known Permian, and older than any fauna described from the European Trias, but they regard the affinities of the species as closer to known Mesozoic types, and the beds were considered as homotaxial with the lower part of the Werfen sandstone the base of the Trias in the Mediterranean region. Now since this part of the Mediterranean section is barren of fossils, this correlation is based entirely on the stratigraphic position of the Ceratite formation.

C. Diener[4], in describing the fauna of the *Proptychites* beds of Ussuri Bay in eastern Siberia, correlated them with the *Otoceras* beds of India, because of the occurrence of several species common to the two regions. It is, therefore, evident that while the correlation of the Ceratite formation of India with the *Proptychites* beds of Siberia and the *Meekoceras* beds of western America may be accepted as correct, the final determination of the age of these beds depends entirely on a comparison with the type of the Lower Trias, the Buntsandstone of Germany, and the Werfen beds of the Alps.

In spite of the weakness of this argument, the Ceratite formation of India has until recently gone unquestioned as the type of the strictly marine equivalent of the Lower Trias, and all correlations of the marine beds have been made by comparison with it. During the last year F. Noetling,[1] paleontologist of the Geological Survey of India, has startled geologists in their fancied security, by the statement, based on his later investigations, that the *Otoceras* beds of India belong to the upper Permian, and are older than the Werfen beds of the Alps. As they lie conformably upon the upper Productus limestone, they represent, according to Noetling, strata of which the equivalents are lacking in the European section. Accordingly he proposes to call the entire Ceratite formation upper Permian, and as a name for the stage he proposes the term Bactrian. If this should prove to be correct it would throw the Ceratite formation of India, the *Proptychites* beds of Siberia, and the *Meekoceras* beds of Idaho and California into the upper Permian.

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[1] Records Geol. Surv. of India, Vol. XIII, 1880. Paleontological Notes on the Lower Trias of the Himalayas, p. 94.

[2] Mem. Geol. Surv. India, Pal. Indica, Ser. XIII. Salt Range Fossils, Vol. II. Fossils from the Ceratite Formation.

[3] *Ibid.*, Ser. XV. Himalayan Fossils, Vol. II, Part I. Cephalopoda of the Lower Trias.

[4] Mem. Com. Geol. St. Petersbourg, Vol. XIV, No. 3. Triadische Cephalopodenfaunen der Ostsiberischen Küstenprovinz.

A. von Kraft,[2] also of the Geological Survey of India, agrees with Noetling, but only as to the Permian age of the *Otoceras* beds; the upper part of the series where *Meekoceras* and *Flemingites* are so abundant he regards as certainly of lower Triassic age. He says that *Medlicottia dalailamae* Diener of the *Otoceras* beds is identical with *M. wynnei* Waagen of the upper Productus limestone, and that *Cyclolobus oldhami* Waagen and *Xenaspis carbonaria* Waagen, which in the Salt Range occur in the middle Productus limestone, in the Himalayas occur in the Kuling Productus shales only twenty or thirty feet below the *Otoceras* beds. This would make the bottom of the *Otoceras* beds (the lower Ceratite limestone) the equivalent of the upper Productus limestone of the Permian. This argument, however, might work both ways, for it would just as well prove that the upper Productus limestone belonged to the base of the Trias, since in any case the division line must be arbitrary. Nor would the finding of *Productus* itself in the *Otoceras* beds prove them to be

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[1] Geol. Surv. of India, General Rept. for 1899 (1900). Notes on the Relationship between the Productus Limestone and the Ceratite Formation of the Salt Range, and Neues Jahrbuch für Min. Geol. und Pal., 1900. Bd. I, p. 139, Ueber die Auffindung von Otoceras sp. in der Salt Range.

[2] Centralblatt für Min. Geol. und Pal. Bd. II, 1901, p. 275, Ueber das Permische Alter der Otoceras-Stufe des Himalyas.

Paleozoic, for if *Otoceras*, *Medlicottia*, *Xenodiscus*, and *Xenaspis* can range into the Mesozoic, there is no known reason why *Productus* should not have done so. Indeed, *Xenaspis* and *Xenodiscus* range up into the Middle Trias, associated with faunas characteristic of the Muschelkalk.

C. Diener[1] meets Noetling's argument by stating that if the Ceratite formation of India is not of Lower Triassic age, then we have nowhere in the world a strictly marine equivalent of the Werfen beds, and that we have the anomaly of Middle Triassic beds lying conformably on Permian. He shows that the marine Permian of the Alps, which lies below the Werfen beds, has not the fauna of the *Otoceras* beds, but one analogous to that of the *Productus* limestone. Diener admits that the *Otoceras* horizon is older than the fossilferous portion of the Werfen beds, but thinks that the rule of priority of reference must be followed, where there are no paleontologic grounds against it and many for it. He also cites a recent paper by A. Bittner[2] to show that there is found in the *Proptychites* beds of Ussuri a typical pelecypod and brachiopod fauna of Werfen character; it must be admitted, however, that this fauna was not found with the ammonites, and might belong considerably above them.

The most direct comparison with the European Trias has been made by Lukas Waagen,[3] who shows that in the Ceratite marls and the Ceratite sandstone of India he has identified a number of pelecypods identical with forms characteristic of middle and upper Werfen beds of the Alps. This leaves the question about as A. von Kraft stated it. The Ceratite formation, from the Ceratite marls up, certainly belongs to the Lower Trias, since the Werfen beds are the type, while the *Otoceras* beds of the Himalayas, or their equivalent, the lower Ceratite limestone, may belong to the upper Permian. But the fauna of the lower Ceratite limestone and that of the Ceratite marls are so similar that a separation of the two is out of the question, and even the genus *Otoceras* is found in the latter. Now, since these doubtful beds are younger than any accepted Permian, and older than any authentic Trias, they might with equal propriety be assigned to either, and we shall have to extend one or the other system to include them. The question will have to be decided either by paleontologic relationship, or by priority of reference. The *Otoceras* beds contain *Meekoceras*, *Proptychites*, *Ophiceras*, and several other ammonite genera that have never been found in the Paleozoic; they contain also *Medlicottia* and *Otoceras* that are more characteristic of Upper Permian; but they lack the Productidae and Orthidae that characterize the Permian formation. Thus the paleontologic evidence is about equal in favor of a reference to either Paleozoic or Mesozoic. But the geologists that described the fauna of the doubtful beds have almost unanimously referred them to the Lower Trias, and this must be the final verdict.

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[1] Centralblatt für Min. Geol. und Pal. Bd. I, 1900, p. 1, "Ueber die Grenze des Perm- und Triassystems, etc."

[2] Mém. Com. Geol. St. Petersbourg, Vol. VII, 1899, "Verstein. aus den Trias-Ablagerungen des Süd-Ussuri Gebietes in der Ostsibirischen Küstenprovinz.

[3] Centralblatt für Min. Geol. und Pal. Bd. I, 1900, p. 285.

The fauna of the *Meekoceras* beds of Idaho and California is most intimately related to that of the Ceratite marls and the lower part of the Ceratite sandstone of India, with most of the genera in common, and several species that seem to be identical. And although the writer has searched carefully for *Otoceras* in both places, no trace either of this genus or of *Medlicottia* was found. It seems likely, then, that even if the bottom of the Ceratite formation should be cut off from the Trias and assigned to the Permian, this change would not affect the nomenclature of our American formations that are now considered as the bottom of the Mesozoic series, and the *Meekoceras* beds will stand as the type of the marine Lower Trias, where White and Hyatt placed them in 1879. The real transition from Paleozoic to Mesozoic must be sought in the conformable series below the *Meekoceras* beds, and above the *Fusulina* limestone.

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